

AD-A195 234

CAN THE NAVY MEET ITS REQUIREMENT FOR ENGINEERS IN THE 1/1
1990S (U) ARMY MAR COLL CARLISLE BARRACKS PA
C L BAILEY ET AL. 28 MAR 88

UNCLASSIFIED

F/G 3/9

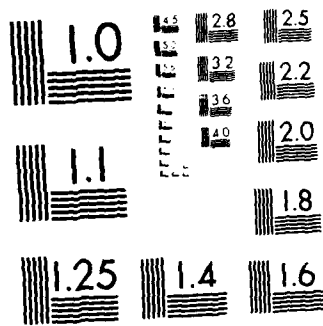
NL

END

DATE

FILMED

8 8



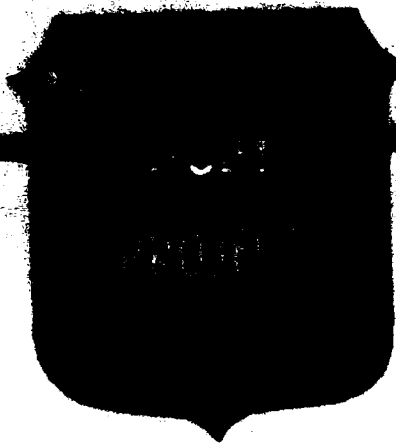
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

AD-A195 234

DTIC FILE COPY

②

The views expressed in this paper are those of the author and do not necessarily reflect the views of the Department of Defense or any of its agencies. This document may not be released for open publication until it has been cleared by the appropriate military service or government agency.



CAN THE NAVY MEET ITS REQUIREMENT
FOR ENGINEERS IN THE 1990s?

BY

COMMANDER CLAUDIA L. BAILEY, USN
COMMANDER FRANCINE F. YORK, USN

DISTRIBUTION STATEMENT A: Approved for public
release; distribution is unlimited.

28 MARCH 1988

DTIC
ELECTE
JUL 05 1988
S E D

U.S. ARMY AND NAVY, CORPUS CHRISTI, TX 78413-5000

88 7 06 036

unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|--|----------------------------------|--|
| 1. REPORT NUMBER | 2. GOVT ACCESSION NO. A105234 | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle) Can the Navy Meet Its Requirement for Engineers in the 1990s? | | 5. TYPE OF REPORT & PERIOD COVERED Study Project |
| 7. AUTHOR(s) CDR Claudia L. Bailey, USN CDR Francine F. York, USN | | 6. PERFORMING ORG. REPORT NUMBER |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army War College Carlisle Barracks, PA 17013 | | 8. CONTRACT OR GRANT NUMBER(s) |
| 11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army War College Carlisle Barracks, PA 17013 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) | | 12. REPORT DATE 28 March 1988 |
| | | 13. NUMBER OF PAGES 44 |
| | | 15. SECURITY CLASS. (of this report) Unclassified |
| | | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |
| 16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution is unlimited. | | |
| 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) | | |
| 18. SUPPLEMENTARY NOTES | | |
| 19. KEY WORDS (Continue on reverse side if necessary and identify by block number) | | |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The Navy's nuclear propulsion program and the effectiveness of its advanced technological systems ashore and afloat are dependent on the acquisition and retention of officers with strong technical educations focused primarily on majors in mathematics, physics, chemistry, or engineering. To satisfy security and sea duty requirements, these officers must be male American citizens. | | |

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

A study of Navy billet requirements as reflected in the President's Budget for fiscal years 1988 and 1989 shows a slow but steady increase in Navy requirements from FY 1988 to FY 1993. As the fleet grows to meet the goal of 600 ships (albeit postponed by the Navy from the early 1990s to the mid 1990s in response to Congressional action in fiscal year 1988) and due to the ever increasing complexity of propulsion systems and weapons systems in Navy ships and squadrons, the Navy's requirement for officers with technical and engineering backgrounds will also grow as we move into the 1990s.

Unfortunately, in light of the Navy's increasing need for technically educated college graduates, there is a disturbing trend in the engineering student population in America which will impact negatively on the Navy's market of recruitable graduates. Not only is the percentage of women and foreign national students in engineering and technical curricula increasing, but at the same time the number of American males between 18 and 24 is decreasing due to the lower birth rates of the 1960s.

This study first discusses the background and methodology used by the Navy to determine its manpower requirements, examines manpower issues regarding engineering officers, and presents Navy requirements for engineering officer billets from 1980 to 1993. Next, American population demographics and engineering college trends are reviewed. Finally, this study compares the Navy's requirements with the engineering student demographic trends, draws conclusions, and proposes several recommendations to ensure an affirmative answer to the question posed by the title.

unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

USAWC MILITARY STUDIES PROGRAM PAPER

The views expressed in this paper are those of the author and do not necessarily reflect the views of the Department of Defense or any of its agencies. This document may not be released for open publication until it has been cleared by the appropriate military service or government agency.

CAN THE NAVY MEET ITS REQUIREMENT
FOR ENGINEERS IN THE 1990S?

A GROUP STUDY PROJECT

by

CDR Claudia L. Bailey, USN

and

CDR Francine F. York, USN

Colonel Marko L. Popovich
Project Adviser

**DISTRIBUTION STATEMENT A: Approved for public
release; distribution is unlimited**

U.S. Army War College
Carlisle Barracks, Pennsylvania 17013
28 March 1988

ABSTRACT

AUTHORS: Claudia L. Bailey, CDR, USN and
Francine F. York, CDR, USN

TITLE: Can the Navy Meet Its Requirement for Engineers
in the 1990s?

FORMAT: Group Study Project

DATE: 28 March 1988 PAGES: 40 CLASSIFICATION: Unclassified

The Navy's nuclear propulsion program and the effectiveness of its advanced technological systems ashore and afloat are dependent on the acquisition and retention of officers with strong technical educations focused primarily on majors in mathematics, physics, chemistry, or engineering. To satisfy security and sea duty requirements, these officers must be male American citizens.

A study of Navy billet requirements as reflected in the President's Budget for fiscal years 1988 and 1989 shows a slow but steady increase in Navy requirements from FY 1988 to FY 1993. As the fleet grows to meet the goal of 600 ships (albeit postponed by the Navy from the early 1990s to the mid 1990s in response to Congressional action in fiscal year 1988) and due to the ever increasing complexity of propulsion systems and weapons systems in Navy ships and squadrons, the Navy's requirement for officers with technical and engineering backgrounds will also grow as we move into the 1990s.

Unfortunately, in light of the Navy's increasing need for technically educated college graduates, there is a disturbing trend in the engineering student population in America which will impact negatively on the Navy's market of recruitable graduates. Not only is the percentage of women and foreign national students in engineering and technical curricula increasing, but at the same time the number of American males between 18 and 24 is decreasing due to the lower birth rates of the 1960s.

This study first discusses the background and methodology used by the Navy to determine its manpower requirements, examines manpower issues regarding engineering officers, and presents Navy requirements for engineering officer billets from 1980 to 1993. Next, American population demographics and engineering college trends are reviewed. Finally, this study compares the Navy's requirements with the engineering student demographic trends, draws conclusions, and proposes several recommendations to ensure an affirmative answer to the question posed by the title.

TABLE OF CONTENTS

| | Page |
|---|------|
| ABSTRACT. | ii |
| LIST OF ILLUSTRATIONS | iv |
| CHAPTER I. INTRODUCTION. | 1 |
| II. NAVY MANPOWER REQUIREMENTS FOR TECHNICALLY TRAINED OFFICERS IN THE 1990S. | 3 |
| Naval Engineering | 3 |
| Naval Engineering Manpower Issues | 5 |
| Navy Manpower Requirements Determination Process | 8 |
| III. ENGINEERING ASSETS IN THE 1990S | 17 |
| Foreign Student Trends. | 20 |
| Females and Minorities. | 24 |
| Quality Engineers | 27 |
| IV. CONCLUSIONS AND RECOMMENDATIONS | 34 |
| BIBLIOGRAPHY. | 37 |

LIST OF ILLUSTRATIONS

- FIGURE 1. NAVY ENGINEERING OFFICER BILLETS
BY DESIGNATOR AND FISCAL YEAR
FROM NAVY MANPOWER DATA ACCOUNTING
SYSTEM (NMDAS) BILLET FILESp. 14
- FIGURE 2. ESTIMATES OF 22-YEAR-OLDS IN
THE U.S. POPULATIONp. 30
- FIGURE 3. TABLE OF HISTORICAL SUMMARY
ENGINEERING ENROLLMENTS IN FALL, 1984
AS COMPARED WITH EARLIER YEARSp. 31

DTIC
COPY
SPECTED
6

| | |
|--------------------|-------------------------------------|
| Accession For | |
| NTIS GRA&I | <input checked="" type="checkbox"/> |
| DTIC TAB | <input type="checkbox"/> |
| Unannounced | <input type="checkbox"/> |
| Justification | |
| By | |
| Distribution/ | |
| Availability Codes | |
| Dist | Avail and/or Special |
| A-1 | |

CAN THE NAVY MEET ITS REQUIREMENT FOR ENGINEERS IN THE 1990S?

CHAPTER I

INTRODUCTION

People are, and always have been an integral part of Navy readiness. Hardware alone cannot do the job; new ships and aircraft and new weapons systems go nowhere and accomplish nothing without the proper manpower to operate them. As we approach the 1990s, the Navy must look ahead to ensure it will be able to man the fleet with the personnel needed to meet national security requirements and Navy missions, as well as maintain personnel and manpower readiness. Thus, the Navy must not only define its own manpower requirements (demand), but must also take a close look at the state of the anticipated sources of supply in the manpower market from which the Navy will recruit and with which it must compete for manpower in this era of the All-Volunteer Force.

The next chapter will review the Navy manpower requirements determination process, examine some current Navy manpower issues relevant to engineering, and assess the Navy requirements statistics (historical and projected) for officers whose mission-critical skills are in either technical fields or engineering. The following chapter will examine population demographics and

their impact on trends in the curricular composition of engineering and technical majors. The final chapter will assess the apparent shortfall between the supply of and demand for engineers for the Navy and make recommendations as to avenues the Navy might investigate to ensure the success of its recruitment efforts to meet its requirements for engineers in the 1990s.

CHAPTER II

NAVY MANPOWER REQUIREMENTS FOR TECHNICALLY TRAINED OFFICERS IN THE 1990S?

NAVAL ENGINEERING

"Naval engineering" is a term encompassing a broad spectrum of talents and functions. As defined by the American Society of Naval Engineers, "Naval engineering includes all arts and sciences as applied in the research, development, design, construction, operation, maintenance and logistic support of surface and subsurface ships and marine craft, naval maritime auxiliaries, ship related aviation and space systems, combat systems, command control, electronic and ordnance systems, ocean structures and fixed and mobile shore facilities which are used by the naval and military forces and civilian maritime organizations for the defense and well-being of the Nation."¹ Obviously, this is quite an extensive definition, and for purposes of this paper, it has been necessary to narrow the scope of that definition. Thus, in determining the Navy's need for engineers, we have examined only the Navy's need for those who possess a background and education in a technical major, including engineering, and who would perform in specific officer billets requiring that background.

Research Methodology

In gathering requirements data for this study, the primary source used was the Navy Manpower Data Accounting System (NMDAS) database, since this is the central, authoritative source used by the Navy to provide Navy's input to the Defense Manpower Requirements Report, the Military Manpower Training Report, and the Navy budget submission each fiscal year. This database is maintained on a continuous basis and interacts with other automated systems to support the Planning, Programming, and Budgeting System (PPBS) and the Congressional processes. Qualitative data includes occupation, paygrade, and other detailed attributes which personnel must possess to perform the work called for by the billet.² The NMDAS database was accessed to derive the manpower requirements statistics presented later in this chapter regarding specific billet requirements (historical and projected) for officers serving primarily in engineering roles, as defined by the Navy Officer Billet Codes assigned to each billet in NAVPERS Manual 15839F (Navy Officer Classifications (Manpower and Personnel)). Other documentation and research included review of formal and informal reports, interoffice correspondence, memoranda, and point papers. In addition, personal interviews were conducted with cognizant personnel within the Office of the Deputy Chief of Naval Operations (Manpower, Personnel, and Training), Naval Military Personnel Command, and Navy Recruiting Command.

While it is recognized that the Navy manpower requirements information presented in this study is not all-inclusive, this chapter provides as factual and complete a picture as possible of Navy billet requirements for officer personnel requiring an engineering or technical major degree for the performance of their duties.

NAVAL ENGINEERING MANPOWER ISSUES

Navy manpower is made up of active and reserve military and civilian personnel. Manpower program development is based on the focus required to execute the military strategy as determined by national security objectives and as constrained by fiscal limitations. As reflected in the FY 1988 Department of Defense Manpower Requirements Report (DMRR) to Congress, the United States is currently committed to developing a 15 Carrier Battle Group, 600 ship fleet in order to meet maritime commitments in support of the National Defense Strategy (even though 1988 Congressional decisions have required that achievement of the 600 ship goal be pushed from the early 1990s to the mid 1990s). To man the new ships and squadrons as they come into active service, the Navy plans to increase manpower levels by 1.0 percent over FY 1987 in FY 1988 and by 1.6 percent in FY 1989.³ Due to the slowdown in the growth of the fleet in response to 1988 Congressional decisions, the figures for FY 1989 may be a bit lower when the FY 1989 DMRR is published, but there will logically still need to be some increase to meet requirements as

ships now under construction come on line. During the current Navy expansion period, the distribution of active military manpower reflects a slow but steady growth in both the number of ships and squadrons and in the support elements of the force, afloat and ashore.⁴ Concurrently, quality manning of the existing fleet must also be given high priority, especially in terms of recruitment and retention of those officer personnel whose mission-critical skills contribute to the fleet readiness and whose talents are in shortest supply (such as doctors, pilots, and engineering officers).⁵ This paper will look only at the Navy's requirements for engineering officers.

One of the top manpower issues facing the Navy today is a shortage of experienced nuclear trained officers beyond the initial term of contract (O-4 through O-6 levels), whose talents are needed in key fleet billets ashore and in such afloat billets as department heads, executive officers, and commanding officers.⁶ Even with relatively good incentive pay and compensation programs, the Navy loses a large number of these officers and other engineering officers to civilian industry each year. Thus there always exists the need to recruit qualified replacements for these anticipated losses in addition to the need to recruit for planned growth to man the expanding fleet. As reflected in the 1988 DMRR, there is a consistent negative balance Navy-wide between Actual/Projected Manpower Inventory, and Programmed Manning (inventory always is lower than programmed manning). This negative balance is especially representative of

the situation found in all technically advanced skill areas such as naval engineering and nuclear power, whose experienced personnel are actively recruited by civilian industry as they reach the end of their initial contract. The FY 1988 DMRR depicts an officer (O-4 to O-6) shortage in inventory as compared to programmed manning each year from FY 1986 to FY 1989, reflecting that the Navy must recruit and maintain an excess of O-1 to O-3 inventory in order to satisfy the requirement for sufficient O-4 to O-6 strength in the long term.⁷

The Navy's engineering officer retention problem is also discussed in the FY 1988 DMRR. Nuclear-trained officers have the lowest Navy officer retention rates (40%), but running a close second is the surface officer community (46%).⁸ This community is comprised of surface warfare officers who fill billets on nuclear and non-nuclear ships and in squadrons, as well as at ashore support commands such as naval shipyards. Many of these officers function in billets requiring technical expertise or an engineering background: engineering duty officers, maintenance engineers, weapons systems officers, etc. It is apparent from these retention statistics that the very officers whose skills are crucial to the Navy are those most attractive to civilian industry also. Therefore, not only must the Navy ensure that its requirements for engineering officers are current, but it must also ensure that effective methods of attraction and retention are used to ensure sufficient quantities of engineers to

compensate for the inventory shortages experienced at the O-4 to O-6 levels.

NAVY MANPOWER REQUIREMENTS DETERMINATION PROCESS

History

In his comprehensive 1977 study of the All-Volunteer Force, Richard Cooper stated "The advent of the All-Volunteer Force (AVF) in 1973 marked the beginning of a new era for the United States military, and indeed, for American society in general. Without the pressure of the draft, the Armed Forces would be forced to rely on the true volunteer as their sole source of manpower...."⁹ With the transition to the AVF, the military manpower procurement method became one of attraction and recruitment, rather than simply assignment of supplied manpower resources to jobs. The military found out quickly that it now needed to be much like any other employer, in direct competition with civilian commerce and industry in its need to attract the desired number and quality of recruits to its ranks. The impact that the initiation of the AVF has had, however, is larger than being simply the difference between recruitment and the draft. Prior to the AVF, the military services could afford to be dominated by policies and traditions without much regard to manpower costs or personnel management practices, since the draft ensured an adequate supply of manpower, no matter what policies were followed. But, as Cooper points out, "...manpower, which

was once plentiful and seemingly cheap, is now scarce and expensive. Policies adopted for reasons of convenience and equity must therefore be evaluated in terms of efficiency as well. In short, manpower is important, so cost-effective solutions to the management problem must be developed and implemented."¹⁰

Indeed, as predicted by Richard Cooper, the Defense Department has sought over the years to refine its manpower requirements determination policies. At the direction of the Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics), the Defense Department increasingly addressed itself to determining the manpower requirements for major weapons systems in development, focusing on the numbers, proficiency levels, and major skill groupings needed.¹¹ This directive has resulted in methods by which the services assess, project, and economize on manpower associated with developmental systems as well as the manpower associated with existing weapons systems or military units, or already-approved system acquisition programs.

Methodology

In 1980, the Navy responded to a Chief of Naval Operations directive to develop a plan to manage and control manpower requirements growth by initiating the Military Manpower versus Hardware Procurement Study (HARDMAN). The HARDMAN program developed analytic procedures used to determine the manpower, personnel, and training (MPT) requirement estimates in the

weapons system acquisition process.¹² Apart from HARDMAN initiatives, the Navy has also developed the comprehensive Navy Manpower Engineering Program (NAVMEP) which provides the capability for planning, programming, and budgeting the manpower resources needed to support both the Navy's operating forces and the shore support establishment.¹³ NAVMEP includes five manpower requirements programs, which are implemented using efficiency reviews that can result in resource adjustments, effected from the top down through the Planning, Programming, and Budgeting System (PPBS). The five manpower requirements programs used by the Navy are: the Ship Manpower Document Program; Squadron Manpower Document Program; Shore Manpower Document Program; Commercial Activities Program; and Navy Manpower Mobilization System. By utilizing the data provided from these programs, the Navy develops documented manpower requirements.¹⁴

Manpower requirements, as contained in the NMDAS database, represent the upper limit of demand to satisfy approved missions or functions for a given workload. Manpower authorizations specify categories of personnel used to perform functions or missions and to indicate a commitment of resources by a service to satisfy a requirement. Navy manpower authorizations are the basis for planning military manpower inventory, not only for the fiscal year being executed, but for projected inventories needed in the five out years of the Navy budget. The figures given as out year requirements carry with them a degree of uncertainty,

since future personnel levels are a function of both resource commitment, and reaction to unforeseen events, such as mandated manpower cuts.¹⁵

NMDAS data on Navy Engineering Officer Billets, 1980 - 1993

In determining which billets would be included in the parameters for the requested NMDAS data run, two factors were taken into account: the designators of officers who fill the billets (as listed in NAVPERS Manual 15839.F, Navy Officer Classifications (Manpower and Personnel)), and the fiscal years to be requested. First, the designators of all nuclear submarine warfare qualified officer billets (112x) were chosen, since statistics provided by Navy Recruiting Command show that, on the average, of all applicants selected for the Nuclear Propulsion Officer Candidate (NUPOC) program with accession dates from FY 1986 to FY 1989, over 90 percent had technical or engineering degrees.¹⁶ It should be noted here that since 1984, the Program Authorization for the NUPOC program has required, among other things, that an applicant be an exceptional student whose major is in mathematics, physics, chemistry, or an engineering curriculum. Thus, the 90 percent figure is not a surprise, since Navy Recruiting Command intentionally targets technical curricula students for the NUPOC market, with only a few applicants from such fields as applied mathematics. The next obvious choice was those billets whose title and job requirements were, by definition, engineering in nature. Thus, 144x (Engineering Duty

Officers), 151x (Aviation Engineering Duty Officers), 153x (Material Professionals), and 510x (Civil Engineering Officers) were chosen to round out the parameters for the requested data run. These billets are by no means the only billets in the Navy requiring engineering expertise, but they were chosen because they contain the largest numbers of officers in engineering fields. There are shipyard, research and development, and weapons systems acquisition billets, for example, that definitely require engineers, but the requirement for them, Navy wide, would number fewer than a dozen officers for each billet code or designator. Consideration was also given to the parameter of subspecialty codes for postgraduate engineering education, but this parameter is not available in the NMDAS database. The fiscal years chosen for the run were FY 1980 through FY 1993. FY 1980 was chosen as a start point to retrieve enough statistical data to examine for historical trends in manning requirements for engineering officers. FY 1993 is the last year of the Five Year Defense Plan (FYDP) associated with the President's FY 1988/FY 1989 Budget, and thus was the logical end date for the data run.

Figure 1 shows that from FY 1980 to FY 1986, the Navy had a steady increase in engineering officer requirements (from 3,836 in FY 1980 to 4,418 in FY 1986).¹⁷ Only a slight decline is reflected for FY 1987 through FY 1989 (from 4,302 in FY 1987 to 4,269 in FY 1989). In the remaining out years, a small increase

in requirements is once again noted (from 4,387 in FY 1990 to 4,402 in FY 1993). The data, then, reflects that the Navy's need for engineering officers has been relatively consistent, does not seem prone to unreasonable inflationary trends, and shows a slow, steady increase into the 1990s.

Every year, the Secretary of Defense, in the Military Manpower Training Report to Congress, makes the following statement: "Since the nation cannot predict when or where war may break out or count on an extended period for mobilization, we must have effective [individuals] to assure that our operational units are capable of carrying out national security missions in peace or war when called upon."¹⁸ In support of that philosophy, the Navy's manpower requirements determination process is designed and executed to give the best possible estimate of billet requirements so that the proper manpower resources can be recruited to meet the Navy's needs.

NAVY MANPOWER ENGINEERING OFFICER BILLET REQUIREMENTS BY DESIGNATOR AND FISCAL YEAR

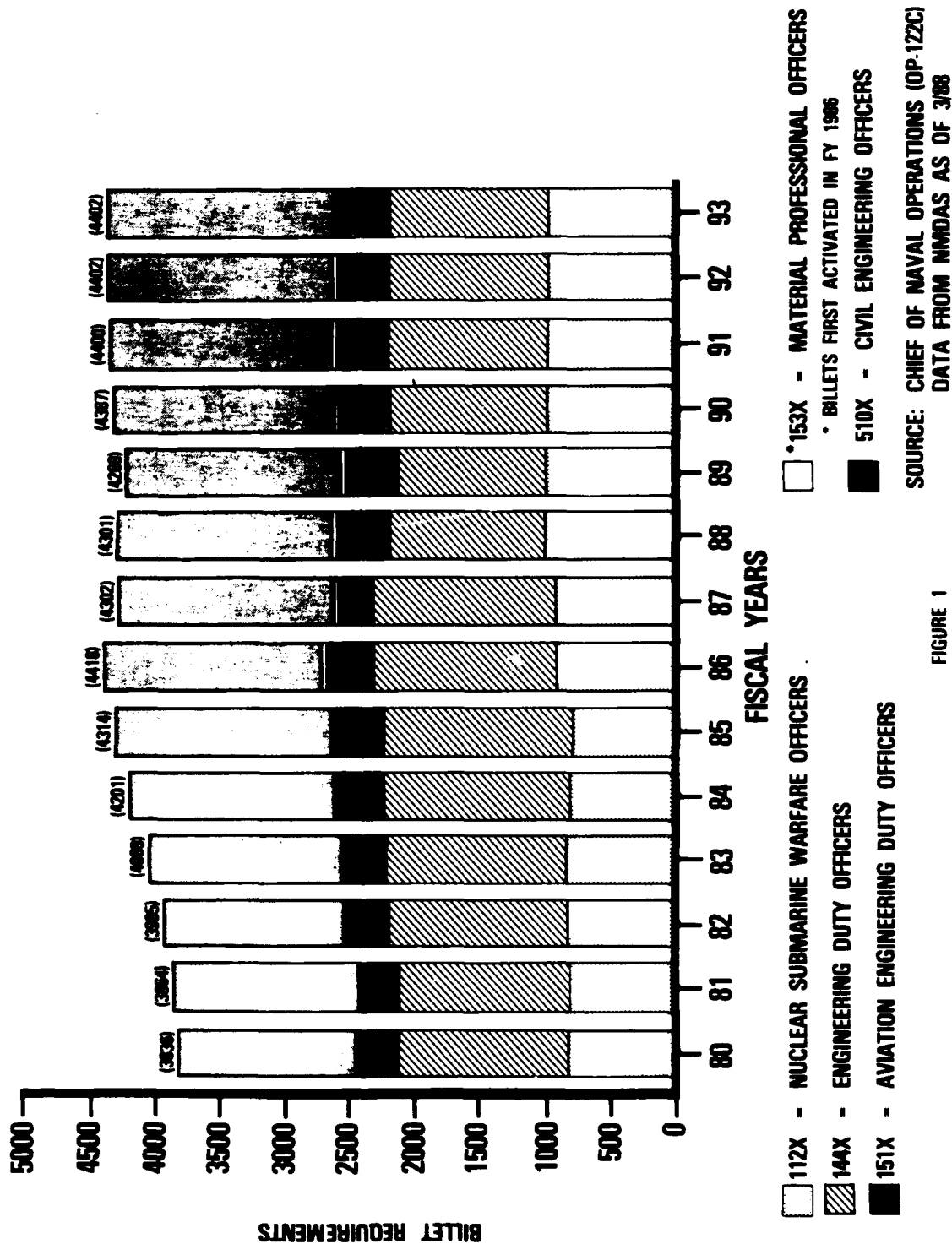


FIGURE 1

ENDNOTES

1. Captain James L. McVoy, USN (Ret.), "Secretary's Notes," Naval Engineers Journal, January 1988, p. 9.
2. Chief of Naval Operations (OP-122), OPNAV Instruction 1000.16F, Manual of Navy Total Force Manpower, p. 3-13.
3. Assistant Secretary of Defense (Force Management and Personnel), FY 1988 Defense Manpower Requirements Report, p. IV-1.
4. Ibid., p. IV-3.
5. Ibid., p. IV-8.
6. Ibid., p. IV-6.
7. Ibid., Pp. IV-12 - IV-16.
8. Ibid., p. IV-25.
9. Richard V. L. Cooper, Military Manpower and the All-Volunteer Force, p. v.
10. Ibid., p. viii.
11. Assistant Secretary of Defense (Manpower, Reserve Affairs & Logistics), Memorandum for Secretaries of the Military Departments, Subject: Manpower Analysis Requirements for System Acquisition, p.1.
12. CDR Grant Fulkerson, HARDMAN Briefing notes, prepared for presentation to Chief of Naval Operations (OP-11), p. 17.
13. Chief of Naval Operations (OP-122), OPNAV Instruction 1000.16F, Manual of Navy Total Force Manpower, p. 2-2.
14. Ibid., p. 2-19.
15. Ibid., Pp. 3-11 - 3-12.
16. Navy Recruiting Command (Code 312 - Head, OCS/Direct Appointments Branch), data run from Navy Recruiting Command data base on Officer Candidate Program Status of Applicants vs Accessions by Technical and Non-technical Majors for FY 1986, FY 1987, and FY 1989, data as of 1 September 1987 for FY 1986 and 1 January for FY 1987 to FY 1989, NUPOC data pages.

17. Chief of Naval Operations (OP-122C), data run executed from NMDAS database on Navy MPN Engineering Officer and Nuclear Propulsion Officer (NUPOC) billets by Designator and Fiscal Year from FY 1980 to FY 1993, data as of end of January 1988, all.

18. Department of Defense, FY 1988 Military Manpower Training Report, p. 8.

CHAPTER III

ENGINEERING ASSETS IN THE 1990S

The previous chapter of this study concerned itself with determining the United States Navy's requirements for engineering resources in the 1990s. This chapter will address the other side of that equation: the engineering resources which will be available in the 1990s. There is more to determining the engineering assets which will be available to the Navy in the 1990s than calculating the total number of engineers in the population during a given timeframe; composition of that population is also very important. The engineering population is changing in many ways, some of which may affect the ability of the Navy to recruit and retain engineers in the 1990s and beyond. This chapter will look at the engineering population trend in the United States as well as the composition factors such as sex, citizenship, and quality in an effort to determine the engineering assets which will be available to the Navy in the 1990s.

As anyone who has served a tour in Armed Forces recruiting or who has heard a politician predict the doom of the Social Security System in this country can tell you, the Baby Boom in the United States during 1946 to 1963 has been followed by the Baby Bust years. Our population is getting older for two reasons: our citizens are living longer and they are having fewer

babies. Since the early 1960s the birth rate in the United States has declined dramatically. The U.S. Department of Commerce has calculated that the total fertility rate¹ for women in the United States was about 1,837 in 1985, which was less than half of the 1957 rate of 3,760. Between 1970 and 1980, the total fertility rate dropped by 26 percent.²

In order for people in their childbearing years to just replace themselves, the total fertility rate would have to be maintained at the 2,100 level. For the sixteen-year period between 1970 and 1985, the total fertility rate for this country has been below 2,100 for thirteen of those years. Some of the negative impact of the low total fertility rate in this country has been masked by the fact that a relatively large proportion of women from the Baby Boom are now in their childbearing years. Immigration has also helped to mask the negative impact. Therefore, the United States has experienced a decrease in its growth rate instead of experiencing a zero or negative growth in its population. However, if the total fertility rate should remain below the replacement rate for a period of forty years and immigration is unable to make up the difference, not only will the United States experience an aging population but it will also experience decreasing population.³ Ben Wattenberg in his controversial book, The Birth Dearth, has addressed some of the negative impacts that can befall industrial nations which fail to have enough babies (i.e., negative economic growth, geopolitical and geocultural shifts, and inability to man the military).

Although our total population is not yet decreasing, we are seeing the effects of a low fertility rate on the college age population which will be available in the 1990s. Figure 2 projects the total number of 22 year olds who will be in the United States population until the year 2000. The 22 year old population peaked in 1983 and will experience a significant decrease during the 1990s.

What does this population trend mean for the engineering schools of the United States? One, it could mean that they will be enrolling fewer engineering students. Two, it could mean that they will have to attract a higher percentage of each high school graduating class to enroll in engineering in order to graduate the same number of engineers each year. Or three, it could mean that they will have to attract more foreign students to their institutions to keep enrollments at their present levels.

The National Science Foundation and other scientific and engineering organizations in the United States have become very concerned with some of the trends they are seeing in the future supply of engineers in the United States. Not only is this country experiencing a decreasing general population of 22 year olds through the year 2000, but it is seeing fewer members of this population enrolling in engineering degree programs. Engineering enrollment for freshmen full-time students has been decreasing from an all-time high of 115,303 in the fall of 1982. By the fall of 1984, that enrollment figure was down to 104,629

freshmen full-time students.⁴ Figure 3 provides historical engineering enrollments for 1977 through 1984.

The decrease in the number of students enrolling in engineering degree programs is only one aspect of the change in the engineering population which will be available in the United States during the 1990s. The composition of the engineering labor force will also be changing in some ways which may affect the Navy's ability to recruit and retain engineering personnel without changing its quality selection criteria. Some of the demographics which are changing and which will be addressed during the remainder of this chapter are citizenship, sex, and quality of the engineers graduating from United States colleges and universities during the next ten years.

FOREIGN STUDENT TRENDS

The engineering enrollment figures given in Figure 3 include all U. S. citizen students and foreign students. Not only has the number of freshmen engineering students decreased in absolute terms since 1982, but the percentage of the engineering classes being filled by foreign students has increased. During the last two decades the number and proportion of foreign students enrolled in American colleges and universities have increased dramatically. "From 1963 to 1983, the percentage of foreign-born doctoral students in industrial engineering grew from 7 percent to 68 percent; in mechanical engineering from 28 percent to 60 percent; in electrical engineering from 23 percent

to 55 percent; in chemical engineering from 22 percent to 52 percent; in civil engineering from 37 percent to 63 percent."⁵ Ten years ago, 20 percent of the Doctorate degrees awarded in physics in this country were earned by foreign students. Today that figure has soared to 55 percent.⁶ It is the doctoral students who fill the research slots in American universities and serve as the role models for future engineers. Perhaps it is mere coincidence, but as the percentage of foreign doctoral students in the academic world has increased, more foreign students and fewer American citizens have enrolled in undergraduate degree programs in these technical areas.⁷

Not only is the decline in the total fertility rate in the United States impacting on the number of engineers who will be available to the military for its technical programs, but the increase in the percentage of foreign students filling American engineering school classes will also impact on the size of the resource pool available to the United States Navy. Because of the requirement for security clearances for many of the technical positions in the Navy, including the Navy's Nuclear Propulsion Program, foreign engineers can not be recruited for these programs.

At first glance it may appear that the increasing number of foreign students attending American engineering schools should be of only minor concern to the Navy. Every year, thousands of American citizens graduate from our engineering schools and the U.S. Navy has a requirement for only a small percentage of that

total. Surely, one might speculate, the Navy could still hire all the American citizen engineering graduates while industry could hire a greater proportion of the foreign citizen engineers. Unfortunately, the solution is not quite that simple.

Ten years ago the United States was the undisputed leader in the world in the areas of technology and manufacturing. Because of our leadership in these areas, most of the engineering graduates, foreign as well as American, were hired by United States industry and stayed in this country to apply their education. The major research and development efforts were taking place in American industry and universities. We were also the major exporter of technology in the world. Therefore, the best and brightest engineers who wanted to be on the "cutting edge of technology" elected to be employed in this country.

Today, the market for engineers is changing. Technology and manufacturing advances and business have become more international in character. The United States is still a major exporter of technology and manufacturing, but other countries, such as Japan and South Korea, have made major advances in these areas during the last ten years. If the present trend continues, it is anticipated that the United States will account for only 20 percent of the world's manufacturing capacity by the year 2000.⁸ Where American industry was the only major employer of engineers ten years ago, Japanese and Korean industry have become serious competitors for engineers educated in the United States. Although 57 percent of the foreign students granted doctoral

degrees in sciences from American universities in 1987 indicated that they planned to stay in the United States, more foreign engineers educated here than ever before are returning to their home countries because there is now a market for their skills there.⁹ Additionally, the foreign industries are growing at such a rate that they are also attracting American engineers to their employ. This has meant that United States industry has had to more actively recruit from the decreasing American engineering population.

If the trend continues, not only will the United States have fewer engineers to meet the military and civilian demand in the United States, but the technology and engineering base of American industry will erode. The erosion of the science and engineering base in the United States has been of major concern to the National Science Foundation, engineering schools, and the United States Congress.¹⁰ One way that the United States can regain its technology base is to increase the number of under-represented United States population groups enrolled in this country's engineering schools. Numbers and percentages of women and minorities have increased in engineering programs during the last ten years, but these groups are still under-represented when compared to their percentages of the American population.¹¹

FEMALES AND MINORITIES

The female workforce in the United States has shown some very dramatic changes during the last fifteen years. A few short

years ago, women worked primarily until they married and had a family. If they worked after marriage, it was to supplement the husband's income. Those women in college were enrolled primarily in nursing, teaching, and other degree programs which would allow them to enter and leave employment as their family situations dictated. To a great extent, women enrolled in college to find educated husbands and did not view their education as preparing them for lifelong careers. Those few women who were in non-traditional technical careers came primarily from families where the mother was a professional career woman.¹²

The economic situation and the women's equality movement in the United States since the 1970s have changed all that. The standard of living expected by the citizens of this country and the cost of living in most major metropolitan areas in the United States have resulted in more working couples than ever before. Not only are more married women working, but they are working longer because of economic necessity. Additionally, they are working longer because they are viewing their work as a career rather than as simply work they will do until they have children or until their husbands are established in their careers.

During the last few years, studies have shown that more women are enrolling in college and more of them than ever before are enrolled in science and technology disciplines such as physics and engineering. Furthermore, their reasons for enrolling in these programs are essentially the same as are those

of their male counterparts. Today, somewhere between 20 and 25 percent of the engineering undergraduates are women and they are performing as well as men students.¹³

Women account for over 50 percent of students enrolled in all undergraduate programs today.¹⁴ Therefore, the National Science Foundation has determined that women are under-represented in engineering, where they comprise only 20 to 25 percent of the undergraduate population.¹⁵ As more and more of these women engineers enter the work force and provide role models for women considering careers, a greater percentage of women will be encouraged to enroll in engineering rather than in the more traditional and less well paying career majors such as education and nursing.

The National Science Foundation is encouraging engineering schools to increase the number of women faculty members at their institutions to increase the visibility of women engineers, provide role models, and attract more women students to their programs. In education, where there are numerous women role models, women comprise over one third of the Doctorate Degree recipients in the total education population, and in 1983 alone, slightly more women than men earned Doctorate Degrees.¹⁶ During 1983 only 5.6 percent of the PhD's in engineering were earned by women.¹⁷ If more undergraduate women in engineering are encouraged to earn Doctorate degrees and become professors, more women are expected to be attracted by these role models.

By attracting more qualified women to enroll in engineering majors in American universities, there should be more engineers available to industry in the United States. This policy should not impact on the number of male engineers graduating each year unless the schools are enrolling less capable males in order to fill their classes at the present time. The average Scholastic Aptitude Test composite score and average American College Test composite score for engineering freshmen has risen from the lows experienced in 1975 to the levels experienced in 1970.¹⁸ Therefore, it does not appear that engineering schools are lowering their standards to admit students. Instead, the engineering schools are electing to admit the best qualified students of either gender.

Engineering schools are admitting a higher percentage of women, but the growth in the number of Blacks and other American minorities enrolling in engineering degree programs has been very slow. Blacks and Hispanics make up 20 percent of the United States population, yet they hold less than 2 percent of the technical degrees in this country.¹⁹ The Black-and-other-races population of the United States is expected to grow to a greater percentage of the population because the fertility level and volume of immigration has been higher for this group than for the Caucasian population. "During 1985, the growth rate was 7.2 per 1,000 for Whites, 21.5 for Blacks and other races combined, and 14.6 for Blacks alone."²⁰ This means that minorities are becoming an increasing fraction of our college age population.

There are many reasons why minority Americans do not enroll in technical degree programs. Like women, minorities have few role models in engineering to encourage them to enter engineering as a career. Additionally, many of the high schools they attend have a low quality of education available and lack adequate levels of science and mathematics needed to pursue science and engineering fields. There are usually low expectations of the students by teachers, counselors and, eventually, by the students themselves. Finally, many of these students have inadequate financial support for college study. The students who are able to attend college, for the most part, attend less financially endowed schools and therefore experience minimal opportunity for undergraduate research, which is necessary to produce the best qualified engineers.²¹

QUALITY ENGINEERS

The number of engineers who will be available to the United States is not the only concern of the U. S. Navy for the 1990s and beyond. The quality of that population is something the Navy will be concerned with as well. Will the engineer of the 1990s and beyond be as well qualified as the engineer of today, or will that engineer be even better educated?

Exposure or lack of exposure to science and mathematics in the early teen years may affect a person's initial decision to seek a career in science or engineering. Students who do not enter the advanced science and mathematics sequence at the

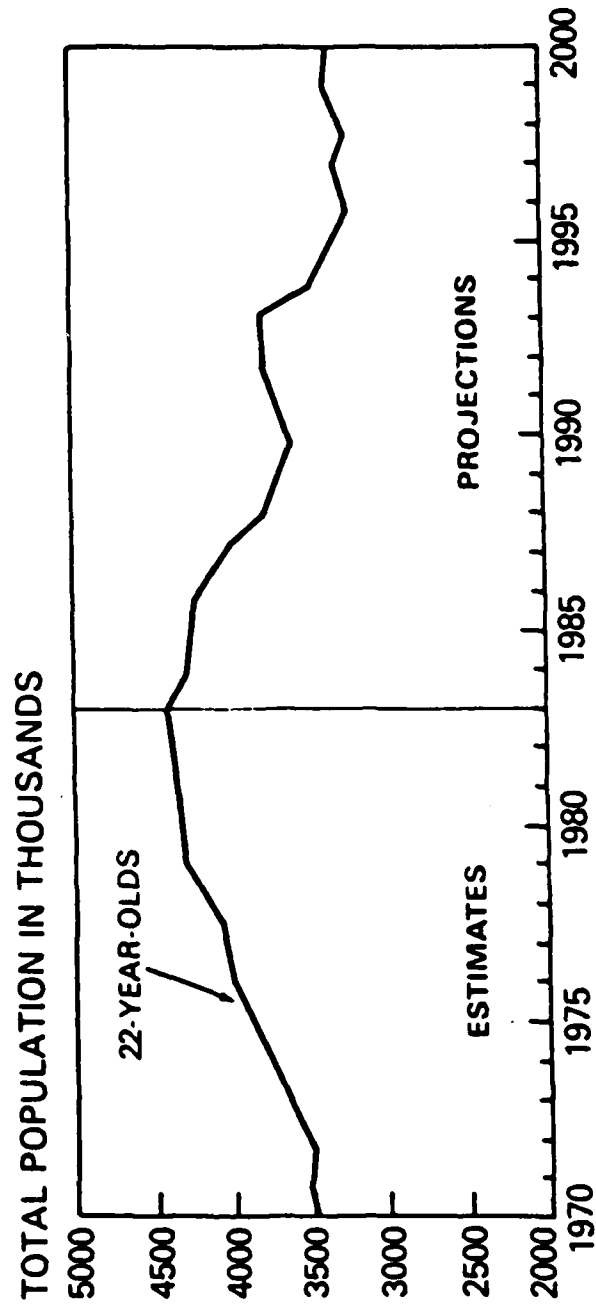
secondary school level are unlikely to be prepared for college-level science courses. Yet in the United States, less than half of secondary school students take more than two years of science and mathematics. Less than 20 percent of these students are exposed to physics.²² Similarly, students without advanced mathematics in high school most likely will not be attracted to or prepared for technical majors such as engineering.

Those students who elect to attend universities to earn degrees in science and engineering may find another problem facing them. Approximately half the nation's bachelor of science degree-granting colleges of engineering are oriented only toward undergraduate instruction. On the other hand, because Federal investment has concentrated on graduate-level engineering research and education, these schools have not benefitted from government programs. The lack of Federal investment has meant that these schools have not had the financial power or facilities to attract the most outstanding faculties.²³ Additionally, these colleges of engineering are experiencing an aging faculty and have been unable to attract a younger replacement faculty because of the higher pay offered in private industry.²⁴ In the aftermath of Sputnik, the Federal government dramatically increased its support to science and engineering education in the 1960s. This was followed by an equally dramatic decrease in this support in the 1970s. By 1969, the United States had an all-time high of 36,000 students supported by Federal fellowships and traineeships. By 1974, those fellowships and traineeships had

declined by two thirds to only 12,000. Since 1975, the number of science and engineering students receiving Federal support has continued to decline, but at a much slower rate.²⁵

Federal spending decreases in research and development at the college level has also impacted the ability of these institutions to replace outdated equipment, attract the most qualified research and teaching faculty, and expose students to the latest engineering advances. The National Science Foundation is concerned that these trends in the education of our future engineers may prevent America from fully realizing the potential of her science and engineering students and competing in the world of technology in the twenty-first century.²⁶

ESTIMATES OF 22-YEAR-OLDS IN THE U.S. POPULATION



SOURCE BUREAU OF THE CENSUS

FIGURE 2

**HISTORICAL SUMMARY
ENGINEERING ENROLLMENTS IN FALL, 1984
AS COMPARED WITH EARLIER YEARS**

| | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 |
|---------------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| ENGINEERING STUDENTS | | | | | | | | |
| Freshman Year, Full-Time | 88,780 | 95,805 | 103,724 | 110,149 | 115,280 | 115,303 | 109,638 | 105,249 |
| Sophomore Year, Full-Time | 70,326 | 72,150 | 78,594 | 84,982 | 87,519 | 89,785 | 89,515 | 83,946 |
| Junior Year, Full-Time | 64,721 | 69,816 | 74,928 | 80,024 | 86,633 | 90,541 | 91,233 | 89,509 |
| Senior Year, Full-Time | 60,109 | 68,260 | 77,823 | 84,442 | 92,414 | 102,055 | 109,036 | 109,695 |
| Fifth Year, Full-Time | 5,312 | 5,206 | 5,419 | 5,520 | 5,731 | 5,706 | 6,722 | 6,236 |
| TOTAL FULL-TIME UNDERGRADS | 289,248 | 311,237 | 340,488 | 365,117 | 387,577 | 403,390 | 406,144 | 394,635 |
| Part-Time Undergraduates | 20,634 | 22,843 | 25,811 | 32,227 | 32,825 | 31,940 | 35,061 | 34,864 |
| Master's Degree, Full-Time* | 26,876 | 26,060 | 27,923 | 29,870 | 32,310 | 33,968 | 38,826 | 37,718 |
| Doctorate, Full-Time | 12,359 | 12,321 | 13,461 | 14,465 | 15,472 | 16,442 | 18,540 | 19,559 |
| TOTAL FULL-TIME GRAD. STUDENTS | 39,235 | 38,381 | 41,384 | 44,335 | 47,772 | 50,410 | 57,366 | 57,277 |
| Part-Time Grad. Students | 25,065 | 24,133 | 25,768 | 28,250 | 29,818 | 31,589 | 33,674 | 35,888 |
| Number of Schools | 289 | 276 | 286 | 287 | 286 | 286 | 292 | 288 |

*INCLUDES ENGINEER PROFESSIONAL DEGREES

SOURCE: Engineering Manpower Commission

FIGURE 3

ENDNOTES

1. "...[T]he total fertility rate is the number of births that 1,000 women would have in their lifetime if, at each year of age, they experienced the birth rates occurring in the specified calendar year. It should be stressed that the total fertility rate is an annual (or period) measure of fertility, even though it is expressed as a hypothetical lifetime (or cohort) measure. The total fertility rate is affected by the timing as well as the level of childbearing." Bureau of the Census, Estimates of the Population of the United States and Components of Change 1970 to 1985, p. 2.

2. Ibid.

3. Ibid.

4. Mobilization Concepts Development Center, Scientific, Engineering, and Technical (SET) Manpower: Critical Elements in Preparedness Planning, p. 21.

5. Jean-Jacques; Servan-Schreiber; and Herbert Simon, "America Must Remain the World's University," Washington Post, 15 November 1987, p. C1.

6. Mobilization Concepts Development Center, p. 2.

7. U. S. Congress, House, Committee on Science and Technology, Scientists and Engineers: Supply and Demand, 1st Sess., Pp. 6-8.

8. Mobilization Concepts Development Center, p. vii.

9. Jean-Jacques; Servan-Schreiber; and Herbert Simon, p. C2.

10. Erich Bloch, Federal Role in Physics Research and Education, Pp. 1-7. Cited with special permission of the National Science Foundation.

11. Ibid., Pp. 4-5.

12. Carolyn M. Jagacinski, "Engineering Careers: Women in a Male-Dominated Field," Psychology of Women Quarterly, 2nd Quarter 1987, Pp. 97-99.

13. Mildred S. Dresselhaus, "Reflections on Women Graduate Students in Engineering," IEEE Transactions on Education, November 1985, p. 196.

14. Bureau of the Census, National Data Book and Guide to Sources: Statistical Abstract of the United States, p. 137.

15. Bloch, p. 5.

16. Dresselhaus, p. 196.

17. Ibid.

18. U. S. Congress, p. 551.

19. Bloch, p. 5.

20. Bureau of the Census, Estimates of the Population of the United States and Components of Change 1970 to 1985, p. 1.

21. U. S. Congress, Pp. 486-488.

22. Ibid., p. 83.

23. Ibid., Pp. 550-552.

24. Ibid., p. 8.

25. Ibid., Pp. 47-48.

26. Bloch, Pp. 10-11.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

A comparison of Navy manpower requirements and trends in the ability of our undergraduate and graduate educational institutions to produce the quantity and quality of recruitable graduates of technical curricula, including engineering, reveals a potential decrease in the Navy's recruitment market. The trends noted in the educational system over the last ten years indicate a decrease in engineering students who will be graduating in the 1990s as well as class composition trends which could well cause problems in the Navy's ability to recruit the best qualified engineers for its needs.

Demographically, there will be fewer American college-aged students in the 1990s. Since 1983, the total enrollment in American engineering schools has decreased. Over the past ten years, the percentage of women and foreign students has been on the rise, and it appears that the trend will continue on into the 1990s. Simultaneously, the minority population in America is growing at twice the rate of the Caucasian population although Blacks and other American minorities are under-represented in the technical degree programs in relation to their representation within the American population. Meanwhile, the Navy's requirement for technically educated male Americans is not decreasing, and continues to remain into the 1990s.

Added to concerns about student population trends, there are several problems inherent in today's educational system. Fewer high school graduates have the requisite math and science background to pursue degree programs in technical curricula in America's colleges and universities. Federal funding for research and development projects and programs has decreased across the board in institutions whose primary emphasis is on undergraduate engineering. These schools have not been able to keep pace with engineering advancements and have not been able to attract high quality students and faculty. In addition, their physical plants, such as laboratory equipment and facilities, are aging along with their faculty. Although students currently graduating from engineering curricula are well qualified, continued under-funding of undergraduate institutions may well erode our technical base in the 1990s.

Because of security and sea duty requirements, it is not likely that the Navy is going to change selection criteria for engineers. They will still be recruited from the American male market pool. Nor is the civilian employment market for engineers likely to change to any large degree. However, the Navy still has several options which, if implemented, could alleviate the anticipated shortage of male American technical major graduates in the 1990s. Some recommended options are:

1. To attract experienced workforce engineers to its direct commission program, the Navy could institute a bonus that

would make it competitive with the civilian job market, or bring in recruited engineer candidates at a rank level commensurate with that experience, as is currently done with medical corps.

2. At little or no additional cost, the Navy Recruiting Command could expand its already successful "Math/Science: Start Now" program to especially target minority schools to encourage students to stay in school and pursue studies that will prepare them for college.

3. Review engineer billet structure within the Navy to determine if any of the billets traditionally filled by men can be performed by women (i.e. shipyard billets, Navy laboratories, shore-based systems commands, etc.)

4. Develop a summer work-study program hosted by the Navy for undergraduate engineering students to familiarize them with Navy opportunities.

5. Expand on the Navy Recruiting Command's Navy Familiarization Visitation Program, now used with doctors and clergy interested in Naval service, to include engineers and engineering school seniors and graduate students.

These recommendations are by no means intended to be all-inclusive and are made without review of their cost-effectiveness, efficiency, or impact on other areas of Navy interest. They are presented simply as suggested areas the Navy might begin to address to prevent the potential problems it may encounter in manning the force in the 1990s.

BIBLIOGRAPHY

1. Assistant Secretary of Defense (Force Management and Personnel). FY 1988 Defense Manpower Requirements Report. Washington, D.C., February 1987.
2. Assistant Secretary of Defense (Manpower, Reserve Affairs & Logistics). Memorandum for Secretaries of the Military Departments, Subject: Manpower Analysis Requirements for System Acquisition, Washington, D.C., 17 August 1978.
3. Assistant Secretary of the Navy (Manpower). Memorandum for the Under Secretary of the Navy, Subject: Manpower. Washington, D.C., 11 July 1980.
4. Assistant Secretary of the Navy (Research, Engineering and Systems). Naval Research Advisory Committee report on Man-Machine Technology in the Navy. Washington, D.C., December 1980.
5. Bailyn, Lotte. "Experiencing Technical Work: A Comparison of Male and Female Engineers." Human Relations, Vol. 40, 1987, pp. 299-312.
6. Bales, Susan M. Lee. The Future of Women in Naval Engineering. Lecture. San Diego: American Society of Naval Engineers West Coast Centennial Symposium, 18 February 1988. (Cited with special permission of Ms. Bales.)
7. Bloch, Erich. Federal Role in Physics Research and Education. Lecture. Arlington, Virginia: Annual Joint Meeting American Physical Society/American Association of Physics Teachers, 28 January 1988. (Cited with special permission of Mr. Bloch.)
8. Bureau of the Census. Estimates of the Population of the United States and Components of Change 1970 to 1985. Washington: U. S. Department of Commerce, 1986.
9. Bureau of the Census. National Data Book and Guide to Sources: Statistical Abstract of the United States. 107th ed. Washington: U.S. Department of Commerce, 1987.
10. Chief of Naval Operations (OP-112D). OPNAV Instruction 1500.8J, Navy Training Planning Process in Support of New Developments, Washington, D.C., 3 April 1979.
11. Chief of Naval Operations (OP-122). OPNAV Instruction 1000.16F, Manual of Navy Total Force Manpower. Washington, D.C., 12 August 1986.

12. Chief of Naval Operations (OP-122C). Data run executed for the author from Navy Manpower Data Accounting System (NMDAS) data base on Navy MPN Engineering Officer and Nuclear Propulsion Officer (NUPOC) billets by designator and fiscal year from FY 1980 to FY 1993, Washington, D.C., data as of end January 1988.

13. Chief of Naval Operations (OP-131E). History of NROTC Policy re Academic Majors, information paper. Washington, D.C., November 1987.

14. Chief of Naval Operations (OP-131E). Letter to Commander, Navy Recruiting Command, Subject: Nuclear Propulsion Officer Candidate (NUPOC) Recruiting Goals, Washington, D.C., 9 September 1986.

15. Chief of Naval Personnel. NAVPERS Manual 15839.F, Navy Officer Classifications (Manpower and Personnel), Washington, D.C., March 1986.

16. Cooper, Richard V.L. Military Manpower and the All-Volunteer Force, A report prepared for Defense Advanced Research Projects Agency by Rand (R-1450-ARPA), Santa Monica, California, September 1977.

17. Department of Defense. FY 1988 Military Manpower Training Report, Washington, D.C., February 1987.

18. Dresselhaus, Mildred S. "Reflections on Women Graduate Students in Engineering." IEEE Transactions on Education, Vol. E-28, November 1985, pp. 196-203.

19. Fulkerson, CDR Grant. HARDMAN Briefing notes, prepared for presentation to Chief of Naval Operations (OP-11), Washington, D.C., 4 September 1980.

20. Harris, Philip R. "Will There Be Engineers for the Next Battle?" The Military Engineer, Vol. 78, July 1986, pp. 376-379.

21. Jagacinski, Carolyn M. "Engineering Careers: Women in a Male-Dominated Field." Psychology of Women Quarterly, Vol. II, 1987, pp. 97-110.

22. Lehman, John., Secretary of the Navy. Memorandum for the Chief of Naval Operations, Subject: NROTC. Washington, D.C., 14 June 1982.

23. McVoy, Captain James L., USN (Ret.). "Secretary's Notes." Naval Engineers Journal, Vol. 100, January 1988, p. 9.

24. Mobilization Concepts Development Center. Scientific, Engineering, and Technical (SET) Manpower: Critical Elements in Preparedness Planning. Washington: National Defense University, 1985.

25. National Science Foundation. Federal Scientific and Technical Workers: Numbers and Characteristics 1973 and 1983. Final Report. Washington: 1985.

26. National Science Foundation. National Patterns of Science and Technology Resources 1984. Washington: 1984.

27. Nauta, Frans. Manpower Planning for the Guided Missile Frigate (FFG-7). Report WN ML801-2, prepared by Logistics Management Institute, Washington, D.C., August 1978.

28. Navy Military Personnel Command (NMPC-440E). Original data compiled for the author of A Count of Subspecialty-coded Engineering Billets in the Navy, from NMPC data base, Washington, D.C., November 1987.

29. Navy Recruiting Command. Navy Engineering Duty Officer, recruiting information pamphlet. Arlington, VA, 1988.

30. Navy Recruiting Command. Naval Engineering Duty Prospectus (pamphlet presented to applicants for Naval Engineering Duty Officer). Arlington, VA, reviewed and approved 1 December 1978.

31. Navy Recruiting Command (Code 312 - Head, OCS/Direct Appointments Branch). Data run from Navy Recruiting Command data base on Officer Candidate Program Status of applicants vs accessions by technical and non-technical majors for FY 1986 (actuals), and FY 1988 to FY 1989 (year-to-date statistics). Arlington, VA., data as of 1 September 1987 for FY 1986 and 1 January 1988 for FY 1987 to FY 1989.

32. Pellerin, Cheryl. "Navy's Procurement System Spawns the '\$7 Engineer'." Washington Technology, 18 February - 9 March 1988, p. 1.

33. Rowden, VADM William H., USN. Keynote Address on Naval Engineering: Challenge of the Next 100 Years. Lecture. San Diego: American Society of Naval Engineers West Coast Centennial Symposium, 18 February 1988. (Cited with special permission of VADM Rowden.)

34. Servan-Schreiber; Jean-Jacques; and Simon, Herbert. "America Must Remain the World's University." Washington Post, 15 November 1987, p. C1.

35. Smith, James P., and Ward, Michael P. Women's Wages and Work in the Twentieth Century. Santa Monica: The Rand Corporation, 1984.

36. Smith, Ralph E. Women in the Labor Force in 1990. Washington: The Urban Institute, 1979.

37. "Status Report." Ms., Vol. XVI, March 1988, p. 73.

38. U. S. Congress. House. Committee on Science and Technology. Scientists and Engineers: Supply and Demand. Hearings, 99th Cong., 1st Sess. Washington: Government Printing Office, 1986.

39. Waite, Linda J., and Berryman, Sue E. Women in Nontraditional Occupations: Choice and Turnover. Santa Monica: The Rand Corporation, 1985.

40. Watkins, VADM J. D. Chief of Naval Personnel, Briefing for Navy Laboratory Directors, Navy Manpower briefing notes, Washington, D.C., dated 16 May 1977.

41. Wattenberg, Ben J. The Birth Dearth. New York: Pharos Books, 1987.

42. "Women in Engineering: A Decade of Progress, 1975-1985." IEEE Transactions on Education, Vol. E-28, November 1985, pp. 181-183.

43. Zars, Belle. "The Statistical Student." Ms., Vol. XV, October 1986, p. 26.

